sample Reactions

Ⓐ Breakdown of sucrose into glucose + fructose

Ⓑ Building sucrose by joining glucose & fructose

Part B: Gibbs Free Energy Calculations

Δ = change

$\Delta G = \Delta H - T\,\Delta S$

What is Entropy? (S) = a measurement of disorder / randomness

When ΔS is positive this means there is more disorder / randomness Ⓐ

When ΔS is negative this means there is less disorder / randomness Ⓑ

What is ΔH? = a measurement of Enthalpy (Heat energy)

When ΔH is positive this means the reaction is endothermic / endergonic (Requires Energy) Ⓑ

When ΔH is negative this means the reaction is exothermic / exergonic [Releases Energy) Ⓐ

What is Gibbs Free energy? (G) = a measurement of spontaneity (whether the reaction will happen on its own without an input of energy)

When ΔG is positive this means the reaction will happen only if energy is added (nonspontaneous) Ⓑ

When ΔG is negative this means the reaction will happen on its own (spontaneous) Ⓐ

ΔG (Joules)	ΔH (Joules)	T (Kelvin)	ΔS (J/K)
-500	1000	300	5
-400	1100	300	5
-300	1200	300	5

What happens to ΔG when ΔH goes up? WHY?

ΔG increases as ΔH increases (if more heat energy input is required, higher H, the reaction will not happen spontaneously) → a more (positive) ΔG

What happens to ΔG when ΔH goes down? WHY?

opposite

ΔG	ΔH	T	ΔS
	1700	300	5
	1700	310	5
	1700	320	5

What happens to ΔG when T goes up? WHY?

ΔG decreases as T increases (a higher temperature means a higher energy of reactants, which means they are more likely to spontaneously collide and react) → a more ⊖ ΔG

What happens to ΔG when T goes down? WHY?

opposite

ΔG	ΔH	T	ΔS
	7500	300	5
	7500	300	10
	7500	300	15

What happens to **ΔG** when **ΔS** goes up ? WHY?

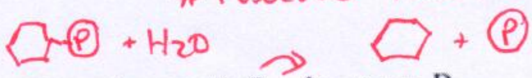
ΔG decreases as ΔS increases (a reaction that results in increased entropy is usually catabolic and exergonic, which means it is likely to occur spontaneously) ↳ A more ⊖ ΔG

Ex: (A)

What happens to **ΔG** when **ΔS** goes down ? WHY?

Ex: (B) opposite

Biochemical free energies are usually given as standard free energies of hydrolysis. For example, the hydrolysis of glucose-6-phosphate: * follow the numbered order! *



(1) catabolic, exergonic (releases energy), spontaneous (−ΔG)

$$\text{glucose-6-phosphate} + H_2O \quad \text{glucose} + P_i$$

Reactants — products

Breaking

has ΔG° = -4.0 kcal/mole (-16.5 kJ/mole) under standard conditions. Therefore, the opposite reaction, the phosphorylation of glucose, is unfavored. However, the phosphorylation of glucose occurs readily in the cell, catalyzed by the enzyme hexokinase:

$$\text{glucose} + \text{ATP} \quad \text{glucose-6-phosphate} + \text{ADP} + \text{phosphate}$$

The other half of the phosphorylation reaction is the hydrolysis of ATP to yield ADP and inorganic phosphate (P_i):

(3) catabolic, exergonic (releases energy), spontaneous (−ΔG)

$$\text{ATP} + H_2O \quad \text{ADP} + P_i$$

Breaking ATP

under standard conditions has ΔG° = -7.3 kcal/mole (-31 kJ/mole).

The standard free energy change of the reaction can be determined by adding the two free energies of reaction:

(2) Anabolic, endergonic (requires energy) Non-spontaneous (+ΔG)

$$\text{glucose} + P_i \rightarrow \text{glucose-6-phosphate} + H_2O \text{ and}$$

$$\Delta G^\circ = +4.0 \text{ kcal/mole}$$

Building

Note that the reaction as written is unfavored; its free energy change is positive. Another way of stating this is that the reaction is **endergonic,** that is, the reaction involves a gain of free energy.

For the **exergonic** hydrolysis of ATP (the reaction involves a loss of free energy):

$$ATP + H2O \ ADP + Pi \ \Delta G° = -7.3 \text{ kcal/mole}$$

The two reactions are summed:

Energy coupling – use the free energy from an exergonic reaction (breakdown/hydrolysis of ATP) to fuel an endergonic reaction (building glucose-Ⓟ)

④

$$\text{glucose} + ATP \ \text{glucose-6-phosphate} + ADP + P_i \text{ and}$$

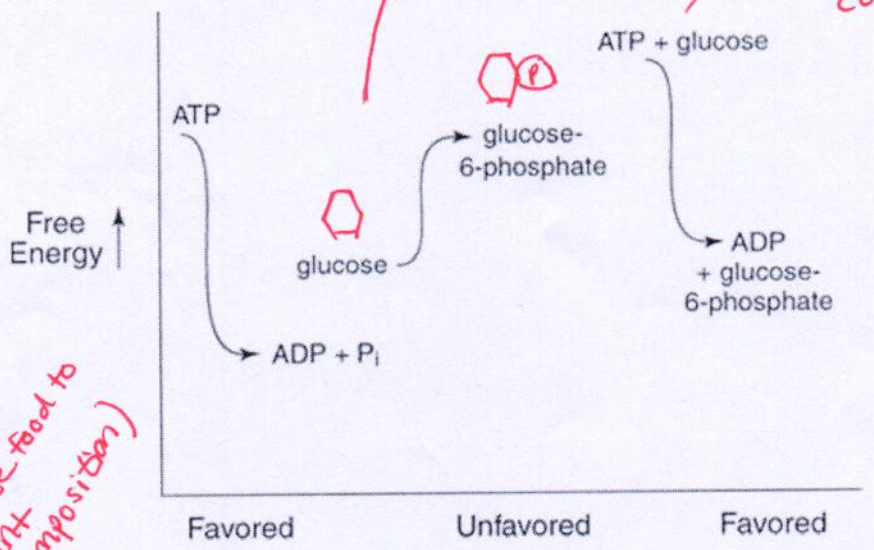
$$\boxed{\Delta G° = -3.3 \text{ kcal/mole}} \quad = \quad -7.3 + 4$$

The overall reaction is spontaneous: ⬡ + ATP → ⬡Ⓟ + ADP (−7.3: breakdown of atp; 4: building of ⬡Ⓟ)

This is a simple example of energetic **coupling,** where an unfavorable reaction is driven by a favorable one, as shown in Figure 1 .

Reaction without energy coupling

Reaction with energy coupling



Note: A dead racoon is more likely to decompose in a room at 85°F than a room at 20°F (we freeze food to prevent decomposition)

Coupling doesn't occur all by itself. In this example, if this experiment were set up so that the ATP would have to be hydrolyzed in one tube and the glucose phosphorylated in another, no coupling would be possible. Coupling can occur only when the partial reactions are part of a larger system. In this example, coupling occurs because both partial reactions are carried out by the enzyme hexokinase. In other cases, coupling can involve membrane transport, transfer of electrons by a common intermediate, or other processes. Another way of stating this principle is that coupled reactions must have some component in common.

The "orderliness" of your body is not favored by free energy. Explain (in terms of free energy and disorder) why you need to perform digestion?

The breakdown of food (glucose) increases disorder (+ΔS) and releases free energy (−ΔG). This free energy can be used to fuel other reactions in the body. (endergonic)

Why does decomposition of a dead animal happen in terms of energy? What would happen if we increase temperature? Why do we freeze food?

2nd Law of Thermodynamics says that entropy should increase (+ΔS). Decomposition involves the breakdown of ordered cells into disorder (+ΔS). This happens spontaneously (−ΔG). Increasing the temperature increases the likelihood that decomposition will happen spontaneously (more ⊖ ΔG)